NATURAL CHANNEL DESIGN PROCESS, USING RIVERMORPH STREAM RESTORATION SOFTWARE

Brian J. Belcher, P.E. and **J. George Athanasakes, P.E.,** RIVERMorph, LLC, 1901 Nelson Miller Parkway, Louisville, Kentucky 40223-2177

ABSTRACT

Over time engineers and scientists have come to the realization that river restoration is a complex process relying heavily on the use of field measurements and empirical relationships. The designer must measure and understand geomorphic parameters within the project reach, have a thorough understanding of the watershed, and must verify that the designed stream will transport sediment without significant agradation or degradation of the channel bed.

A very popular method for designing natural stream channels consists of measuring geomorphic parameters from a reference reach and then "sizing" the reference reach parameters to match the design reach through the use of dimensionless ratios. To expertly use the reference reach approach for natural channel design, extensive geomorphologic data must be collected and analyzed during the design process. This data collection and analysis is time consuming and sometimes requires much iteration.

RIVERMorph LLC has developed a software package for the evolving stream restoration profession. This software processes geomorphologic data and is useful for assessment, monitoring and natural channel design. Relying on proven design techniques, this software streamlines the stream design, leaving the designer more time and budget for data collection and monitoring.

THE EVOLVING SCIENCE OF STREAM RESTORATION

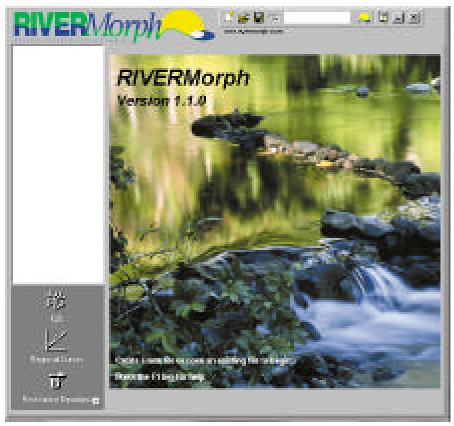
Stream restoration as a science has evolved from ancient river training techniques used for irrigation, navigation and flood control projects into modern ecological restoration plans designed by teams of engineers, geomorphologists, biologists and skilled construction contractors. In the past decade the profession has witnessed a trend in stream restoration that started with bioengineered or "natural" bank stabilization practices that tended to address the effects of stream degradation, but is now focussing on cross sectional, planform and longitudinal geometry best suited to exist in the natural landscape. The later approach tends to address the causes of stream degradation, channelization for example, and mitigates those causes by mimicking natural systems that are stable in similar environments.

The art of restoration is in the way professionals condense reams of input data into construction drawings illustrating natural stream systems. Given a beginning point and ending point, a stream can form nearly infinitely many planform alignments; however, there are many times when only one or two alignments can work with all the site constraints.

RIVERMorph has been developed to allow designers to restore rivers on a meander wavelength scale, with the ability to iterate design constraints quickly in each wavelength. The outcome is a natural appearing stream system with variability in its planform, longitudinal profile and cross-section dimensions.

DEVELOPMENT OF THE RIVERMORPH SOFTWARE PACKAGE

Research and development for the software began in 1999. At this time research was focused on resistance equations and shear stress calculations needed for bank stabilization design. Later, basic geomorphologic data collection and stream classification were added to the first application (alpha version), which was developed in 2000. The software went through further development, including the addition of natural channel design equations, GIS, regional curves and graphing capabilities, until beta[1] testing in 2001 by private consultants, universities and government agencies. After incorporating revisions from the beta test and the latest available design algorithms, Version 1.0 was released in June, 2002.



DESCRIPTION OF RIVERMORPH CAPABILITIES

RIVERMorph is a product that combines useful techniques and algorithms from a variety of successful restoration professionals. The software is based on the philosophy that streams can be redesigned into stable reaches that exist harmoniously in the surrounding landscape and that this design process should be based on empirically derived relationships between stable streams and their inputs, i.e. water, sediment, flora and fauna.

RIVERMorph provides a data structure for the essential geomorphologic characterizations, and has data input forms for the following information:

I. Survey Data
   a. Total Station
   b. Field Book
II. Cross Sections
III. Longitudinal Profiles
IV. Particle Size Analyses
   a. Pebble Counts
   b. Sieve Analysis

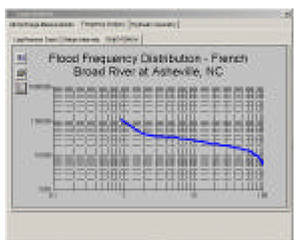
[1] Beta testing is the process of getting feedback from peers and potential users.

V. Stream Classification
VI. Pfankuch Channel Stability Analysis
VII. Stream Visual Assessment Protocol
VIII. Natural Channel Design
IX. Cross Vane, W-Weir and J-Hook
X. Design
XI. Geographic Information System (GIS)
XII. Regional Curves
XIII. Resistance Equations
XIV. Regime Equations (Williams)
XV. Gage Analysis

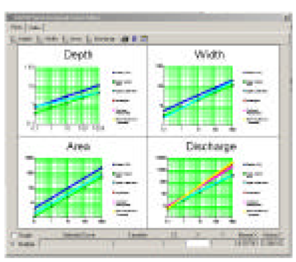
Input depends primarily on the intended use. Typically the input for a natural channel design involves unreduced survey data, pebble count data and bulk material sieve analysis data. Output includes calculated results stored in the database, reports and graphs that can be used to generate typical sections and details.

DESIGNING A STREAM RESTORATION PROJECT WITH RIVERMORPH

Restoration designs with RIVERMorph involve field data collection, design calculations, validation and conversion of results into construction drawings. The following description outlines the general process and tools available within the software to facilitate natural channel design.

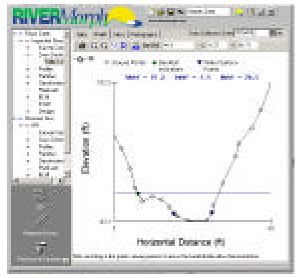


RIVERMorph calculates flood frequency distributions and hydraulic geometry from downloaded USGS gage data.

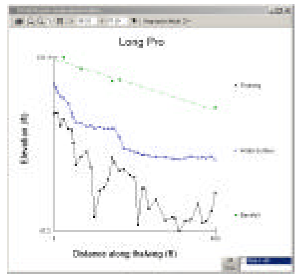


Regional Curves are displayed on interacted graphs that can be used to estimate cross sectional geometry as a function of drainage area.

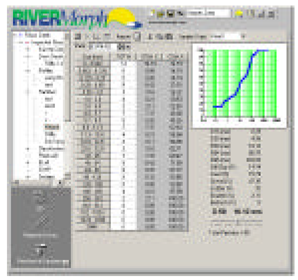
1. Gage Analysis and Regional Curve Development
    a. Before field work, it is a good idea to download gage data from any nearby USGS gaging stations. RIVERMorph provides utilities for searching the USGS website and downloading peak discharge data into the RIVERMorph Project. The software can then be used to perform a flood frequency analysis and to generate hydraulic geometry for the gaging station. Begin field excercises at the gaging station and determine what elevation bankfull passes through the gage.
    b. Using a rating curve supplied by the local USGS office, you can then "calibrate" your ability to find bankfull elevation in other streams nearby. Also, the information from the gage can be used to plot a single point on a new regional curve for your area. RIVERMorph comes with some industry standard curves, like the Upper Salmon River by Emmett, 1975.
2. Impacted Reach Survey
    a. RIVERMorph defines a "reach" as a length of stream equal to approximately 20 to 30 bankfull widths. Determine the number of reaches along the impacted site and perform a geomorphic survey in each reach in accordance with Harrelson, 1994.
    b. The geomorphic survey is composed of a longitudinal profile, cross sections and sediment analyses. Begin by collecting the longitudinal profile data, marking locations where riffle and pool cross sections will be taken. Data should be gathered with frequency



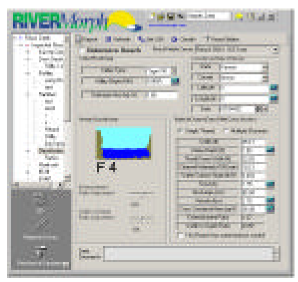
Unreduced survey data is processed and graphed by the software. Cross sectional metrics width, mean depth and area are displayed on the graph.



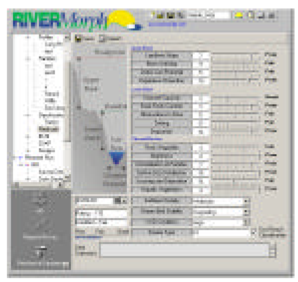
This interactive longitudinal profile graph has a slope, depth and distance measuring tool to allow the user to quickly compile the dimensionless ratios needed for design.



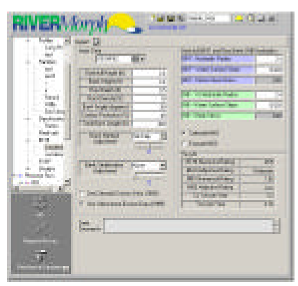
Pebble count and sieve data is graphed and analyzed in the particle analysis module.



Once the survey data has been entered and reduced, RIVERMorph classifies the reach in accordance with the Rosgen Stream Classification System (Rosgen 1994).



The Pfankuch Channel Stability module is used to indicate the relative stability of the reach.



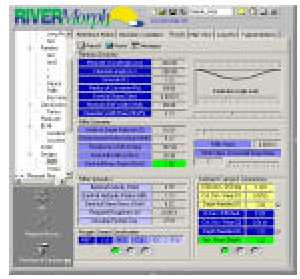
Bank erosion rates can be predicted using the Bank Erosion Hazard Index (BEHI) module.

sufficient to define pools, runs, riffles and glides, and should include the low flow water surface, bankfull elevation and other significant features, such as top of bank and terrace elevations.

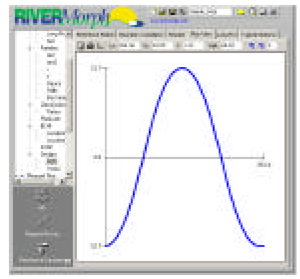
3. Reference Reach Survey (Rosgen 1998)
    a. The same geomorphic survey described above is performed in the reference reach.
    b. A biological assessment (USDA 1998) and channel stability assessment (Pfankuch, 1975) are performed in the reference reach.
4. Natural Channel Design Calculations
    a. Once the impacted reach and reference reach data has been input to RIVERMorph, the natural channel design module can be used to quickly iterate on a design until the proposed geometry matches the reference reach classification and has the ability to transport its sediment, as validated using critical dimensionless shear stress calculations (Parker, 1990 and Andrews, 1995).
    b. Typical details for the plan view alignment of the channel thalweg and longitudinal profile are automatically produced by the software. Cross sectional details are customized by the user to generate the shape of the proposed channel that best suits the channel materials and reference reach patterns.
5. Grade Control and Bank Stabilization Structure Design

    RIVERMorph includes design calculations for W-Weirs, J-Hooks and Cross Vanes. In smaller rivers, Cross Vanes are typically used for grade control structures. RIVERMorph is used to generate and validate Cross Vane geometry and spacing for the proposed reach.

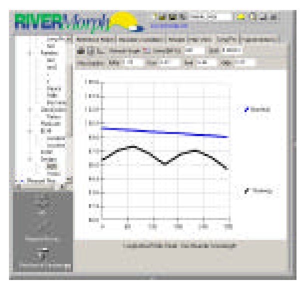
The Stream Visual Assessment Protocol (SVAP) module is used to rate the biological habitat of the reference reach.



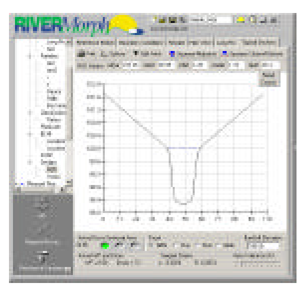
This Natural Channel Design module has slider controls, allowing the user to modify meander wavelength, deflection angle, meander width ratio, width to depth ratio and the riffle slope ratio while recalculating related parameters.



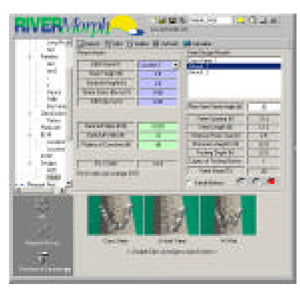
The plan view detail plots the thalweg coordinates for 1-10 meander wavelengths using a sine-generated curve (Soar and Thorne, 2001).



A longitudinal profile detail is created for the designed reach showing maximum depths in riffles, runs, pools and glides in each meander wavelength.



RIVERMorph uses Bezier curves to allow the user to customize the cross section details. The user can easily reshape the cross section and see the area, width, etc. updated.



The Vane module is used to design Cross Vanes for grade control structures. It also allows the user to design W-Weirs or J-Hook Vanes (Rosgen 2001).

6. Regime Equation Validation
   The regime equations provided in RIVERMorph are very useful for providing a check for your design. Typically the equations are used to compare the design to the relationships of radius of curvature to width, meander wavelength to radius of curvature and others.
7. Regional Curve Validation
   The design geometry should be consistent with Regional Curves developed for the project area. If there are no existing Regional Curves for the site, RIVERMorph can be used to construct them if some stable reaches and preferably gage sites can be located in the watershed or surrounding area.
8. Design Output
   RIVERMorph generates tables of design geometry, as well as tables of coordinates for cross sections, plan view and longitudinal profile. These tables can be supplied to the CADD department for development into design drawings, or can be imported into GIS using “event themes”.

CONSTRUCTION AND MONITORING

RIVERMorph is a powerful tool to use during the construction process if unknown site conditions require a field change to a portion of the alignment, such as when shallow bedrock is encountered. Changes to the stream geometry, such as narrowing the meander belt width, can easily be evaluated using the software’s slider controls. RIVERMorph will adjust all the related channel dimensions and validate the sediment transport competency of the adjusted channel.

It is also crucial to collect as-built geomorphic survey data immediately after construction to begin the monitoring process. Ideally, reconstructed streams would be monitored for the long term; however, monitoring budgets are sometimes limited or entirely absent. The RIVERMorph project file used to design the reach is an excellent place to store any monitoring data collected in the new reach, making it easy to generate reports and to evaluate changes over time.

REFERENCES

Andrews, E.D. and Nankervis, J.M. Effective Discharge and the Design of Channel Maintenance Flows for Gravel-Bed Rivers, *Natural and Anthropogenic Influences in Fluvial Geomorphology, Geophysical Monograph 89.* American Geophysical Union, 151-164, 1995.

Emmett, W.W. The Channels and Waters of the Upper Salmon River Area, Idaho, *Hydrologic Evaluation of the Upper Salmon River Area, Idaho, Geological Survey Professional Paper 870-A*. Washington: U.S. Government Printing Office, 1975.

Harrelson, C.C., Rawlins, C.L., and Potyondy, J.P. *Stream Channel Reference Sites: An Illustrated Guide to Field Technique: General Technical Report RM-245*, Fort Collins, CO: U.S. Department of Agriculture - Forest Service, Rocky Mountain Forest and Range Experiment Station, 1994.

Parker, G. Surface-based bedload transport relation for gravel rivers, *Journal of Hydraulic Research, Vol. 28, No. 4,* 417-436, 1990.

Pfankuch, D. J. Stream Reach Inventory and Channel Stability Evaluation. U.S. Department of Agriculture, Forest Service/Northern Region. 1975.

Rosgen, D.L. A classification of natural rivers, *Catena*, *22*. Elsevier Science B.V., 169-199, 1994.

Rosgen, D.L. The Cross-Vane, W-Weir and J-Hook Vane Structures…Their Description, Design and Application for Stream Stabilization and River Restoration, *Proceedings of ASCE 2001 Wetland and River Restoration Conference*. Reno: ASCE, 2001.

Rosgen, D.L. The Reference Reach – A Blueprint for Natural Channel Design. Denver: ASCE, 1998.

Soar, P.J., and Thorne, C.R. *Channel Restoration Design for Meandering Rivers*. Nottingham, U.K.: University of Nottingham School of Geography, September 2001.

USDA. *Stream Visual Assessment Protocol*, *National Water and Climate Control Technical Note 99-1*. U.S. Department of Agriculture, Natural Resource Conservation Service, December 1998.